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NASA Integrated Network Continuity of Operations (COOP)

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Background

- NASA Integrated Network Architecture Trade Studies were chartered to respond to the requirement to develop a unified space communications and navigation architecture.
  - Objective of the studies is to select the best-value architecture alternative
  - Overall architecture divided into multiple studies for ease of managing the effort
    - Studies closely coordinated and the interactions between the options were closely monitored
    - Early in the process, determined that the Continuity of Operations (COOP) preparedness was tightly linked to every aspect of the architecture studies
    - This paper discusses the COOP study effort

Acknowledgments

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Part of the study was carried out at the JPL/Caltech, under a contract with the NASA.

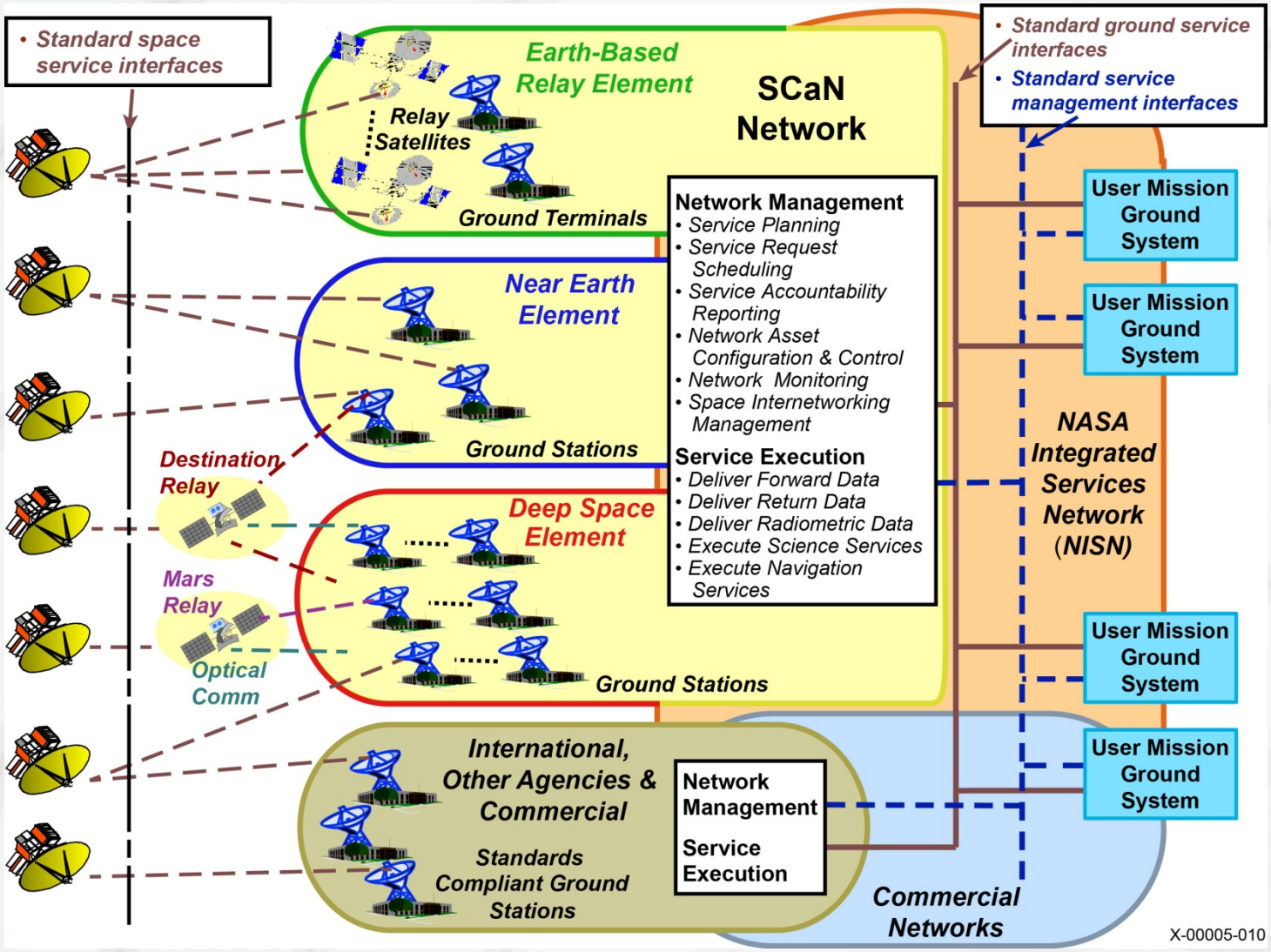
Key COOP Requirements

- As a baseline for preparedness, NASA Headquarters and NASA Centers are required to have in place a viable COOP capability that ensures the performance of their mission-essential operations during any type of emergency or other situation that may disrupt normal operations.
- A viable COOP capability must:
  - be maintained at a high level of readiness
  - be capable of being implemented with and without warning
  - be operational within 12 hours of activation
  - maintain sustained essential operations for a minimum of 30 days
  - take maximum advantage of available field infrastructure, existing Agency emergency preparedness program procedures, and established Information Technology (IT) Security plans.

Key COOP Requirements

- Key requirements from NPR were used to develop integrated network COOP requirements such as:
  - SCaN Network COOP Readiness
    - The SCaN Network COOP capability shall be operational within 12 hours of activation.
  - SCaN Network COOP Sustainability
    - The SCaN Network COOP capability shall maintain sustained essential operations for a minimum of 30 days from activation.
- Integrated network requirements flowed down to element level requirements such as:
  - COOP Mission-Essential TDRS Operations Criteria
    - Under a COOP scenario, the EBRE shall maintain the capability to provide monitoring and control of the TDRS fleet sufficient to ensure TDRS fleet health and safety.
  - COOP Mission-Essential TDRS User Operations Criteria
    - Under a COOP scenario, the EBRE shall maintain the capability to provide services necessary to ensure user mission health and safety.

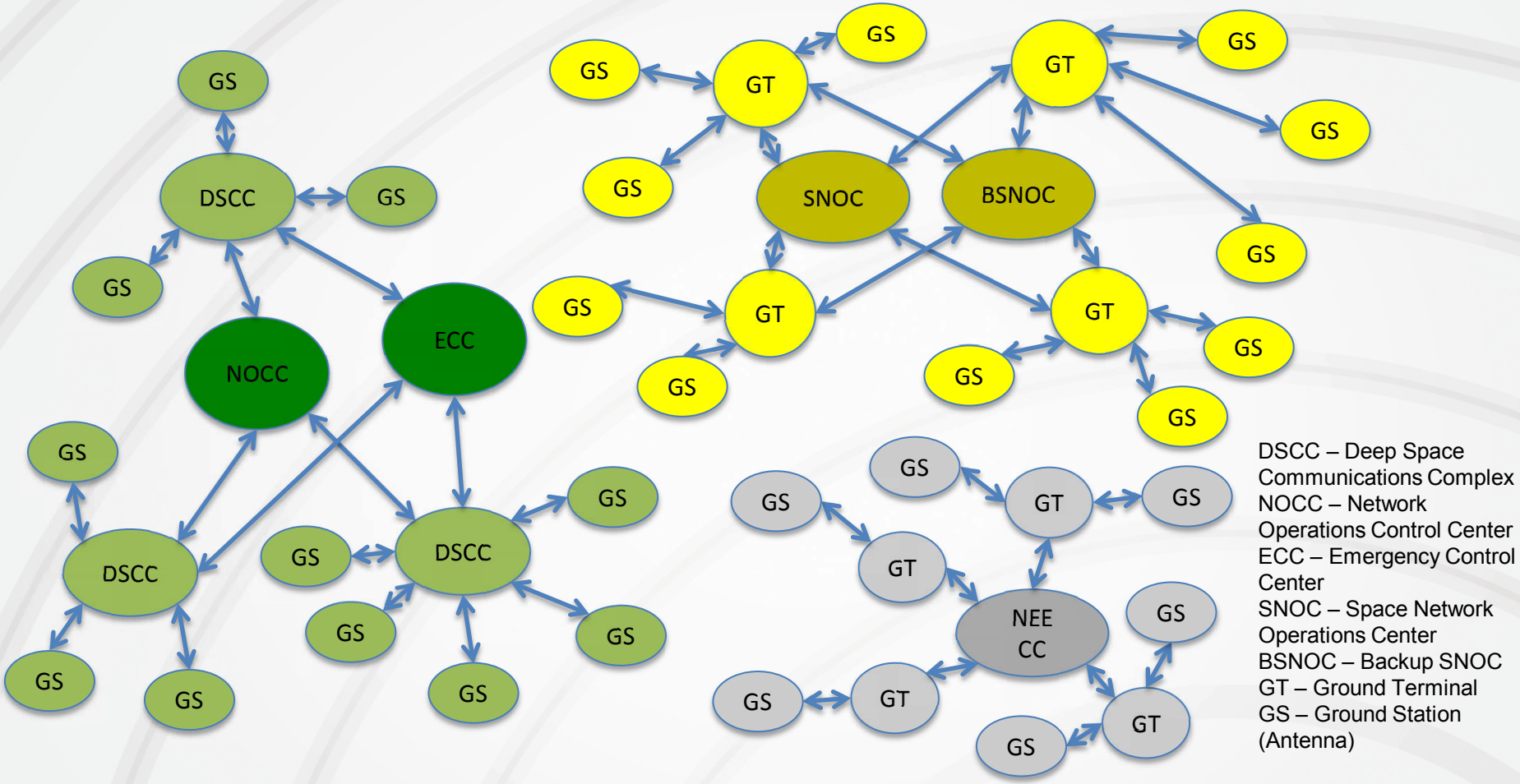
“Should-be” Architecture



Current COOP Approach

- Current COOP approach managed by each individual network element
  - Each element relies on the diversity of ground stations and relay elements to provide COOP for service execution
  - Each has back-up capabilities within their respective elements for scheduling and network control
  - Each implements their own plans to restore service within their individual element
- Some users can utilize multiple network elements and may request services from a different element if there is a failure in their normal element
  - It is the user's responsibility to initiate the change
- No plan to address COOP from an overall SCaN network perspective in the current phase

Current COOP Approach



Network Control COOP addressed independently at each Network Element

Near Earth Element (NEE)

- All missions supported by NEE can be supported by more than one NEE station
- Contracts with commercial providers provide additional redundancy
- Many missions supported by NEE can also be supported by the Deep Space Element (DSE)
- Reciprocal agreement with National Oceanic and Atmospheric Administration (NOAA) to provide back-up support
- Back-up scheduling system located at Wallops Island
  - Provides capability to manually schedule supports
- By Point-of-Departure (POD), circa 2018, NEE will have adopted a centralized Monitor and Control (M&C) approach
  - Ground stations will have personnel on-call to operate locally if necessary

Deep Space Element (DSE)

- Each DSE Deep Space Communications Complex (DSCC) has multiple Ground Stations that can, with some limitations, be used interchangeably
  - If an entire DSCC is inoperable, critical missions can be supported by the other stations
- Agreements in place with international partners to use their deep space networks if required
- Central Network Operations Control Center (NOCC) provides network schedules and pointing data and a Data Systems Operations Center (DSOC)
  - Geographically separated Emergency Control Center (ECC) provides limited back-up capability
- Radio Science support curtailed during COOP event

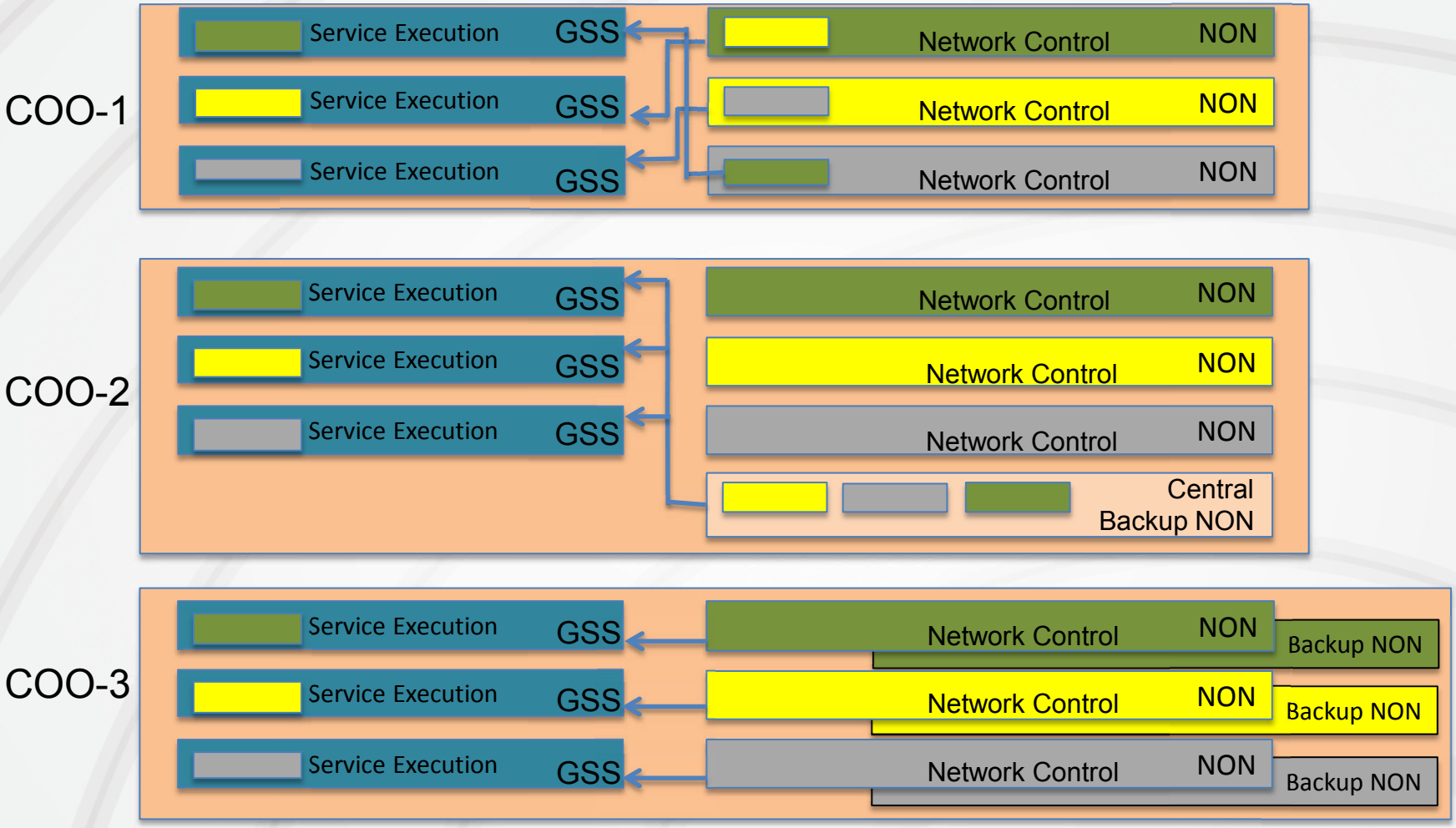
Earth Based Relay Element (EBRE)

- Three ground terminals provide Tracking Data Relay Satellite (TDRS) TT&C and user services
  - Each ground terminal has multiple antennas providing TT&C and user services for multiple TDRS
  - Redundant scheduling, monitor & control, and fleet management at two of the ground terminals
  - Fourth terminal being developed to extend coverage in the Atlantic Ocean region.
  - Redundant terminals and TDRSs provide back-up for user services
- S-band only antennas provide additional TDRS TT&C support
  - Not capable of providing user services
  - Used to support on-orbit spares, TDRS relocation, and contingencies
  - External S-band assets (NEE, DSE, commercial) used when necessary
- Implementation of SN Ground System Sustainment (SGSS) project and addition of new terminal will enhance COOP posture

Integrated Network COOP Approach Alternatives

OPTION	DESCRIPTION
COO-1 Cross support backup between network elements	Each network element (EBRE, NEE, or DSE) relies on another network element to provide backup capabilities for network control in time of disastrous events for maintaining COOP. This implies, for network control functions, that a Network Operations Node (NON) hosts or serves as the backup NON for another network element.
COO-2 Central back-up	A single site, at a geographical location different from any of the NONs for the three network elements, provides backup capabilities for network control to all network elements in time of disastrous events for maintaining COOP.
COO-3 Self confined backup at each network element	Each network element (EBRE, NEE, or DSE) provides backup capabilities for network control by itself within its own system and performs backup activities in time of disastrous events for maintaining COOP. No cross-support among network elements takes place. This implies that within each network element there exists a backup site hosting or serving as the backup NON.

Integrated Network COOP Options System Context



COOP and Software Options are highly correlated

Network Control Software Options

Options	Description
NCS-1 - Common network control framework	Common software framework for the entire network control functionalities across all network elements, i.e., EBRE, NEE, and DSE. Such a software framework includes common code providing generic network control functionality, but can be selectively adapted or specialized by network elements, thus accommodating network asset-specific functionality.
NCS-2 - Common network control interface	Common software components (within the network control function) that provide the interfaces with human operators, service management, and user mission elements.
NCS-3 -Central gateway	A singly implemented and centrally deployed gateway that functions as the single interface point (for the network control function) with the service management and user mission elements. The gateway performs necessary protocol conversions for the dissimilar and network asset-specific network control interfaces at the various network elements, i.e., EBRE, NEE, and DSE.
NCS-4 - Network element gateway	Multiply deployed gateways that function as the interface points (for the network control function) with the service management and user mission elements through common interface protocols. The gateway at each network element, i.e., EBRE, NEE, and DSE, performs necessary protocol conversions for the dissimilar and network asset-specific network control interfaces in each element.

Integrated Network COOP Approach / Software Architecture Matrix (1 of 3)

	COO-1 Cross-support backup between network elements	COO-2 Central back-up	COO-3 Self-confined backup at each network element
Network Control Systems NCS-1 through NCS-4	Software/databases at each back-up facility must be kept up-to-date. Routine proficiency passes must be done. Communications for each supported element must be provided and regularly tested.	Software/databases at each back-up facility must be kept up-to-date. Routine proficiency passes must be done. Communications for each supported element must be provided and regularly tested.	Software/databases at each back-up facility must be kept up-to-date. Routine proficiency passes must be done. Communications for each supported element must be provided and regularly tested.

Integrated Network COOP Approach / Software Architecture Matrix (2 of 3)

	COO-1 Cross-support backup between network elements	COO-2 Central back-up	COO-3 Self-confined backup at each network element
NCS-1 Common network control framework	Sufficient hardware must be replicated at a back-up facility to support the element being backed up. A common framework minimizes training, but personnel must be trained in element-specific processes.	Sufficient hardware must be replicated at the central back-up facility to support all three networks, although not necessarily at the same time. A common framework minimizes training, but personnel must be trained in element-specific processes for all three networks.	Sufficient hardware must be replicated at each back-up facility. Personnel must be trained in element-specific processes for supported network.
NCS-2 Common network control interface	Sufficient hardware must be replicated at a back-up facility to support the element being backed up. A common framework minimizes training, but personnel must be trained in element-specific processes.	Sufficient hardware must be replicated at the central back-up facility to support all three networks, although not necessarily at the same time. A common framework minimizes training, but personnel must be trained in element-specific processes for all three networks.	Sufficient hardware must be replicated at each back-up facility. Personnel must be trained in element specific processes for supported network.

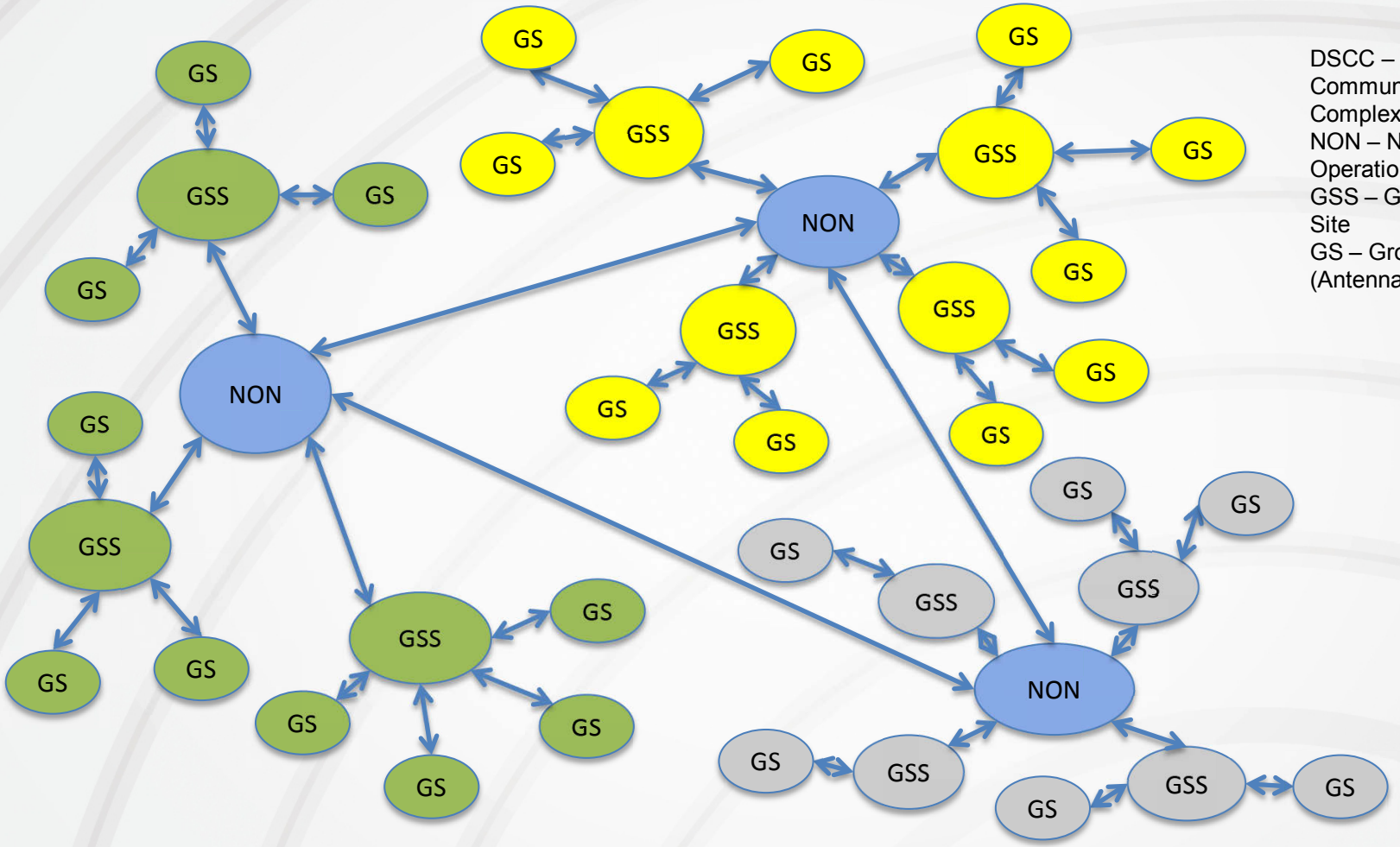
Integrated Network COOP Approach / Software Architecture Matrix (3 of 3)

	COO-1 Cross-support backup between network elements	COO-2 Central back-up	COO-3 Self-confined backup at each network element
NCS-3 Central gateway	The central Gateway must be replicated at each back-up NON. Network specific M&C hardware and software must be replicated at each back-up NON. Personnel must be trained in element-specific systems and processes.	The central Gateway must be replicated at the central back-up NON. Network specific M&C hardware and software for each network must be replicated at the back-up NON. Personnel must be trained in element specific systems and processes.	Sufficient hardware must be replicated at each back-up facility. Personnel must be trained in element specific processes for supported network.
NCS-4 Network element gateway	A central Gateway must be replicated each back-up NON. Network-specific M&C hardware and software must be replicated at each back-up NON. Personnel must be trained in element-specific systems and processes.	A central Gateway must be replicated the central back-up NON. Network-specific M&C hardware and software must be replicated at the back-up NON. Personnel must be trained in element-specific systems and processes.	Sufficient hardware must be replicated at each back-up facility. Personnel must be trained in element specific processes for supported network.

Evaluation Process

- COOP options were evaluated along with the NCS options
  - Identified key figures-of-merit (FOM) that were considered important attributes of a new integrated network
  - FOMs were then weighted by relative importance and scored on an option-by-option basis
  - Effort was made to estimate the relative cost of each option
  - Technical merit of each option was then compared with the relative price and a best value judgment was used to determine the final recommendation

Integrated Network Architecture Era COOP Approach



DSCC – Deep Space Communications Complex
NON – Network Operations Node
GSS – Ground Station Site
GS – Ground Station (Antenna)

Element NONs provide backup to other NONs

Results

- Common network monitoring and control software deployed at all network elements (i.e., the NCS-1 approach) coupled with the cross support backup between network operation centers (i.e., the COO-1 approach) were chosen for the initial implementation of the integrated network
  - Provides best value when considering cost and technical merit
  - COOP requirements for service execution are met with geographically distributed ground stations
  - Network control capabilities for each network element are replicated at another network element
    - Each network element will be backed up by at least one other element
    - Provides an inherent ability to achieve COOP in time of disastrous events
    - Operational proficiency at the supporting network element maintained through the occasional cross support to the supported network element and proficiency supports

Acknowledgment

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